WINEMAKING BASICS

C.S. OUGH, DSc, MS

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Cornelius S. Ough, DSc, MS

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This effort is fully dedicated to Anne – my wife and true friend of many years – whose courage and spirit were a great inspiration and driving force, not only for this book but also for my life.

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Preface

This book is for the winemaker in a medium or small operation who plans to make table wines or champagne. It is also for the intelligent home winemaker who wishes to know more about winemaking than adding two teaspoons of this or that and stirring with a clean stick. Without some background in chemistry and biochemistry, it may be difficult in places. An effort has been made to explain in the simplest terms possible and still not forsake the real meat of the problems.

A very abbreviated description of planting and growing a vineyard is offered. This is aimed primarily at the home wine enthusiast. What is said applies to all viticulture, however.

Some of the chapters are more intense than others. To a degree this reflects the author's personal interests. An effort has been made to be complete and up-to-date in each area.

The Bibliography covers most of the current texts that should be of interest to the winemaker. If some favorites of others are omitted, it is because what was given seems to cover the field adequately. References older than 1980 were kept to a minimum. Emphasis has been on the literature published after that date. Most of the literature to that time has adequately been covered in the texts cited in the Bibliography.

The analysis chapter is complete for routine analyses. Other texts are available for the more complex analyses. Commercial winery design was not covered because of the complexity and the need for specific needs for specific wants. Waste removal, by-products such as yeast, color, tartrate recovery, distillation, brandy production, dessert wine and specialty wines are not covered. Government regulations are readily available by request from the proper agency and are always in flux and need to be followed consistently.

This book is meant to be a guide, not a bible, to table winemaking. The differences in style that can result from the variations that can be applied in the winemaking process are for the winemaker to choose.

Cornelius S. Ough

Introduction

Wine types have changed rather rapidly as have the technologies associated with the various wine types. This has led to a shift in production of dessert wines to table wines around the world. In the United States, this has been a very dramatic change in wine consumption (see Table A). The reasons for this are perhaps because of technology more than anything else. Before the 1950s, good drinkable dry table wines could only be made from grapes grown in the limited, cooler, coastal regions. With improvements that did not alter the sensory aspects of the wine, such as cool-controlled fermentations, cultured yeast inocula, sterile filtration and cold sterilization chemicals, good table wines were made from the warmer areas. The wines from the colder areas improved in quality as well. For those who were familiar with the "vin ordinaire" of Europe before the 1960s or 1970s, it was obvious that significant changes took place there also.

Table A. Change in Wine Consumption Pattern in the United States

	Gals/capita		
Type	1950	1979	1987
Table wines	1.08	2.56	2.01
Dessert Wines[1]	0.77	0.44	0.34
Other wines[2]	--	--	1.09

[1]All wines over 14% v/v alcohol.
[2]Includes coolers, natural special wines under 14% alcohol, sparkling wines.

In California, growers changed the grape varieties that they planted to better suit the need for the wine market. These changes reflected the demand for the varieties that produced the highest quality table wines. This was not unique to California, but California was the leader in this area. The newer grape-growing areas, such as Australia, South Africa, and some older ones, have followed suit. A great deal of credit for these changes has to be given to work done by Amerine and Winkler (1963) in their extensive evaluation of the growing regions and their variety recommendations. Table B shows how the variety plantings have changed since their influence was felt. Since this survey, the trend toward planting prestigious table wine varieties continues. Others certainly contributed also. Leadership of industry people like the Gallos had a deciding impact. They took the recommendations to heart and also did their own testings, and insisted on planting the better wine varieties.

These changes have not been as dramatic for the older established areas of Europe. The variety selection has gone on for hundreds of years and the optimum grape cultivars were known and planted. However, the impact of change has taken its toll. The dessert wine and sherry countries have a much smaller share of the world wine market. Extensive plant modification and upgrading has taken place in Italy and France. The Balkan countries are beginning to modernize their plants and make some changes in what is planted. As with everything, these changes come with a price—that price is evident when the consumer goes to the store. The increased prices and better production practices of growing grapes, plus changing social habits, have caused a worldwide glut of wine.

The winemaker in a competitive winery must still strive to improve and make a wine that is unique yet has high quality with certain recognizable features. How well he/she succeeds in this determines only partially the probability of success. How efficiently the plant is operated and how expertly the product is sold to wine writers, distributors, and the public, are also factors in the winery's economic survival.

Many times the winemaker is the only scientifically trained person in the winery. The training must include a broad knowledge of chemistry, biochemistry, bacteriology, a working knowledge of statistics, engineering, business and management skills. Also, one

Table B. Acreage Changes in Wine Cultivars in California Over 42 Years[a]

Cultivar	1944	1986
Whites		
Burger	2987	2496
Chardonnay	<500[b]	29319
Chenin blanc	<500	40088
Colombard	1480	NA[c]
Emerald Riesling	0	2583
French Colombard	<500	69713
Gewurztraminer	<500	3659
Gray Riesling	<500	1761
Malvasia Bianca	NA	2237
Muscat blanc	NA	1531
Palomino	5072	2372
Pinot blanc	<500	2031
Saint Emilion	<500	1009
Sauvignon blanc	<500	15193
Semillon	<500	2724
Sylander	574	725
White Riesling	<500	8449
Other whites	8780	274
Total	23893	186164
Reds		
Alicante Bouschet	25606	2858
Barbera	<500	13417
Cabernet Sauvignon	<500	23149
Carignan	32051	14347
Carnelian	0	591
Gamay	NA	2282
Grenache	4229	14669
Mataro	7692	456
Merlot	<500	2881
Mission	10906	1883
Petite Sirah	7721	4983
Pinot Noir	<500	10842
Royalty	0	999
Ruby Red	0	7334
Ruby Cabernet	0	9319
Salvador	NA	922
Tinta Madeira	<500	739
Zinfandel	50349	25797
Other reds	16747	468
Total	157801	137936

[a]1 acre=0.4047 ha.
[b]<500 was taken as 330 for the purposes of total acreage.
[c]NA=Either less than 500 acres or listed under 'Other whites' or 'Other reds'.

should have a thorough understanding of viticulture including knowledge of cultivar identification, maturity testing of grapes and fruit quality. Consultants are available but expensive, so one must decide based on his/her experience and training. This can be a very lonesome job when a 25,000-gallon tank of Chardonnay develops a peculiar odor or taste. One must make a plan to abort a potential problem and cure the ill. Is it due to a yeast or bacteria or is it some chemical action? Did one of the workers drop a wrench into the tank, etc.? The tank of wine could be worth $100,000 or more to the winery but, if spoiled, only a fraction of that. Nowadays it is a very scientific and serious business.

Chapter 1

Grapes and Concentrate

The source of the raw material for winemaking is of vital importance to the quality of the wine produced. Several options exist for winemakers or winery owners: (1) grow their own grapes, (2) buy grapes from local vineyards, or (3) buy grapes to be shipped to them. Of all the choices, the first can be the most rewarding if local growing conditions are favorable. The winemaker needs a moderate understanding of grape-growing (viticultural) practices. Most commercial wineries deal only with options (1) or (2). They generally grow their own grapes, have a trained viticulturist or hire an appropriate vineyard consultant to advise them.

VINEYARD

Before planting even a small vineyard, there are many variables to consider. The selection of the scion (top) of the vine and the rootstock onto which it will be grafted must be such that the two are compatible with each other. They must be compatible with the climate and the soil. The following questions must also be answered. Do pests, such as phylloxera, Pierce's disease, or nematodes exist in the area? Is the rootstock resistant to the soil pests? Is there adequate soil depth, drainage or moisture in the soil? Is there freedom from chemical imbalance? Will the location provide adequate sunlight? How does one find the answers to these and other questions?

The best solution is to seek qualified advice. In areas where grapes are grown, the local farm advisor or county agricultural agent will be able to answer the questions, generally at no cost to the winemaker. In an area where grapes are not grown, then it would be wise to seek the help of a qualified viticulturist. It would also be prudent to obtain a textbook on grape growing such as *General Viticulture* [Winkler et al. (1974), University of California Press, Berkeley, California].

From the time a vineyard is planted until the first good crop of grapes is harvested is from four to five years. Under favorable growing conditions it is possible to obtain a crop in three years. The fruit from the young vines is often chemically imbalanced and the wine is not a true representation of the vines' potential. Overcropping young vines can do serious harm to the vines, even to the point of stunting or killing them.

There are certain clichés which are worth considering: (1) if grapes are not grown in your area, there is probably a very good reason for it, and (2) the wine you make will only be as good as the grapes (or material) it is made from.

Preparing for and growing a vineyard can be a costly project. It can also be a very rewarding one both financially and personally. The personal aspects include "your wine from your grapes." Harvest time is usually August to September or October. The leaves are turning to bright colors, the weather is mild and pleasant with a feeling of fall in the air. Memorable times can result.

Most high quality grapevines planted in wine-growing areas yield about three to seven tons of grapes per acre depending on the variety and the location. Most home winemakers can expect to get 80-110 gallons of juice per ton of grapes using the equipment available to them. With the more sophisticated presses, yields up to 140-160 gal/ton are possible. Yields on red grapes fermented on the skins will be about 20% higher because of the ease of pressing. Planting more than one acre of grapes will put the home winemaker over any reasonable amount of wine for home use. Depending on the spacing between the vines, an acre will contain 500-600 grapevines.

Growing Conditions

There are several growing conditions which will affect the composition of the grape and the quality of the wine. Among these factors are climate, soil, fertilization, irrigation, pest control, virus infections, crop level and other cultural practices.

Climate is probably the most important single identifiable factor which can alter the final wine quality. Grapes grown in warm climates tend to lose their acidity more rapidly than grapes grown in cooler regions. This is due primarily to the enzymatic decomposition of malic acid during the maturation of the grape. The warmer the climate, the more rapidly the loss of malic acid occurs. This is one of the many biochemical changes taking place in the grape as it ripens. The tartaric acid, the other major acid in grapes, is more resistant to decomposition and less change occurs. Most of these changes are caused by enzymes and each has an optimum temperature at which the most intense enzymatic activity takes place. Another example of the effect of climate is how the varietal character of Sauvignon blanc is altered by climate. In the cool vineyards of Monterey County in California, the Sauvignon blanc has a strong and distinct character when it reaches full sugar maturity. On the other hand, in the warm San Joaquin Valley in California you can find the same varietal character, at lesser intensity, when the grape is about two-thirds mature; but the varietal characteristic has disappeared when full sugar maturity is reached. In some cases, the varietal characteristic is so intense in the cooler climates that it precludes growing it in those areas.

Grapevines need to go dormant to survive the winter cold. This is best accomplished by a cool fall with light to medium frosts which allows the vine to store sufficient carbohydrates to sustain adequate spring growth. If these conditions do not exist, then the vines are easily damaged by sudden intense winter cold and may be killed. On the contrary, in the warm semi-tropical areas, they may go only partially dormant. Insufficient carbohydrate reserve will be stored for adequate growth and fruit set the following year.

Climatic conditions affect the degree to which the grape or grapevine will be subject to mold, rot or mildew. For example, White Riesling will rot on the vine before it is mature in the warm and heavily irrigated vineyard areas. In any area that has summer rains or is heavily irrigated, the vines are subject to powdery mildew (oidium) or worse, downy mildew (peronospora) under the wettest conditions. Fruit quality is badly impaired when molds are not controlled. When overirrigated, varieties with tight clusters such as Zinfandel have a tendency for the berries to swell and burst. This allows mold and rot to occur. Usually the berries that rupture are in the center of the cluster and the entire cluster becomes contaminated. This can be avoided by planting these tight cluster grapes in the dryer areas and avoiding irrigation as the berries reach full size.

Soil Pests

The soil pests most common in the northern hemisphere are nematodes and phylloxera. Nematodes (round worms), usually found in sandy soil, suck nutrients from the roots of the vines. Poor growth and delayed grape maturity result. Such stunted vines seldom yield good quality grapes. Nematodes are controlled by fumigating the soil with chemicals before planting the vines. Choosing nematode-resistant rootstock is necessary. Certain nematodes also spread viruses which affect the grapevine. Phylloxera is a root louse (insect) native to the eastern United States. The native American grapes were shipped to various areas of the world for experimentation. These vines were not sterilized before shipment so they carried the phylloxera with them. This caused great damage in Europe and other grape-growing areas in the middle to late 1800s. It was a great economic tragedy. The life cycle of the pest is quite interesting and complex. In the grape-growing areas of the world that receive little or no summer rains (California, Israel, South Africa, etc.), the winged form of the pest is not present. The infestation of this pest then can be noted by an ever-widening circle of dead or stunted vines from the point of infestation. These pests also suck nutrients from the roots and are more prevalent in the heavier soils than in the light sandy loam-type soils. Again, the treatment is soil fumigation and proper selection of rootstocks. A graft of a resistant rootstock to a scion is shown in Figure 1-1. Data from a typical rootstock trial is given in Table 1-1. This was on Ballard clay, cane pruned, with set sprinkler irrigation (Foott et al., 1989). Under other conditions, different results may be obtained.

Soil

In Europe, soil is considered a major factor in determining wine quality. Scientifically sound proof of this remains to be shown. Conditions such as extreme acidity or alkalinity will cause problems

FIGURE 1-1. A vine showing the graft joint a few inches above the soil. (If graft is below the soil, roots from the scion may form.)

Table 1-1. A Comparison of Rootstock Interactions on Pruning Weights and Crop Levels for Cabernet Sauvignon and Chardonnay Scions.

	Pruning Weights (lb/vine)		Crop Yield (lb/vine)	
Rootstock	Cabernet Sauvignon[1]	Chardonnay[2]	Cabernet Sauvignon	Chardonnay
1202C	6.5[a]	2.7[a]	14.1[ab]	20.6[ab]
5A	4.5[b]	2.1[b]	13.5[ab]	21.6[a]
St. George	4.4[bc]	1.3[c]	12.4[b]	16.0[bc]
SO_4	4.2[bc]	1.5[c]	14.4[ab]	15.5[c]
Own	4.1[bc]	1.8[bc]	13.5[ab]	17.9[abc]
3309C	4.0[bc]	1.6[c]	12.6[ab]	19.0[abc]
AxR#1	3.9[bc]	1.8[bc]	15.8[a]	21.7[a]
110R	3.2[bc]	1.3[c]	12.5[b]	15.1[c]
Harmony	3.0[c]	1.3[c]	9.1[c]	9.5[d]

[1]Average of four years' harvests.

[2]Average of three years' harvests.

[a-d]Values with the same superscript in the vertical columns are not significantly different.

From Foot et al. (1989)

in vine growth. This, in turn, affects the wine quality. Normally, it is adequate if the soil is three or more feet deep, has good drainage and is at a reasonable pH. Other deficiencies can usually be remedied by proper treatments and/or additions. It is best to have an expert evaluate the soil if there are any doubts about planting grapes. At that point the need for, and type of, irrigation should be considered. Additions of fertilizer should be moderate. Most soils have adequate nutrients. For soils with depleted nitrogen, additions of over 50 pounds of nitrogen per acre are wasteful as excess top growth can result with no gain in crop. It can also lead to excess nitrogen compounds in the wine which can encourage spoilage as well as possible formation of ethyl carbamate.

Planting

Verification is made that the conditions of the climate and soil are adequate for a vineyard. The soil is plowed, disced and fumigated (if required). The field is laid out in rows using a surveyor's transom. The easiest type of plants to use is grafted plants in pots. These can be planted anytime in the spring after danger of frost has passed.

In shallow soil it is useful to lay black plastic around the vines to hold in moisture and heat. It will also help control weeds. If water is available, several good irrigations will help establish the root system sooner.

The usual insect and fungus protection should be applied to the young vines.

It is important that reference to viticultural literature be made or consultation obtained so that a thorough awareness of all facts of vine planting and maintenance is available before planting.

Irrigation

Grapes are deep-rooted plants and require little irrigation after the vines are established. Over-watering will encourage excess cane growth, delay in fruit maturation and poor carbohydrate storage for winter and spring vine reserves. If the soil is shallow, more frequent but smaller volume application of water should be made. Mature vines planted in deeper soil require only one or two heavy irrigations during the summer in the warm areas and none in cooler areas. If the grapes are grown where summer rains occur, no additional water applications should be made. If too much water is used, the delay in sugar maturity allows acidity and flavor losses to occur. Also, picking may be delayed until the rainy season which allows the opportunity for mold and rot to infect the grapes.

It should be emphasized that outside consultation is recommended for the amateur grape grower if any questions arise.

Pruning, Trellis and Yield

The proper time to prune your grapevines is in the winter after they have gone dormant and the canes have hardened (turned brown). There are several styles of pruning: head (or bush), cordon and cane. General schematic examples of each of these styles are shown in Figure 1-2. Although other pruning and trellis styles may give better yields, for the home vineyard the simplest is the most satisfactory.

Each vine should be staked and the vine trained up the stake during the first growing season. Only one shoot should be trained and all the others pinched off. Figure 1-3 shows a one-year-old grafted vine ready to train. Figure 1-4 shows a typical three-year-old grafted vine that has been trained up the stake and onto a two-wire horizontal trellis. An example of a vertical two-wire trellis for cordon-spur pruned wines is shown (Figure 1-5).

The number of buds, canes or spurs to leave on the vine depends on the size and vigor of the vine. More buds may be left on the larger and more vigorous vines. If an extremely large crop sets, then some thinning of the clusters may be necessary. Actual thinning should be considered carefully. Ough and Nagaoka (1984) found that when a normal crop could be matured to a desired °Brix and pH, thinning did not increase wine quality. The loss in quantity

FIGURE 1-2. Schematic drawing of A) cane pruned vine, B) head pruned vine, and C) cordon-spur pruned vine.

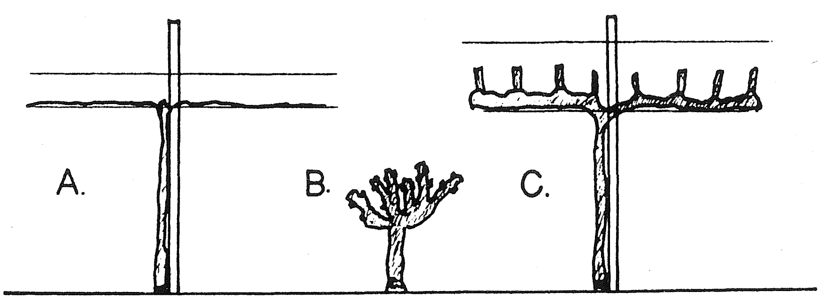


FIGURE 1-3. A young grafted vine ready to cut back to one shoot and train up the stake.

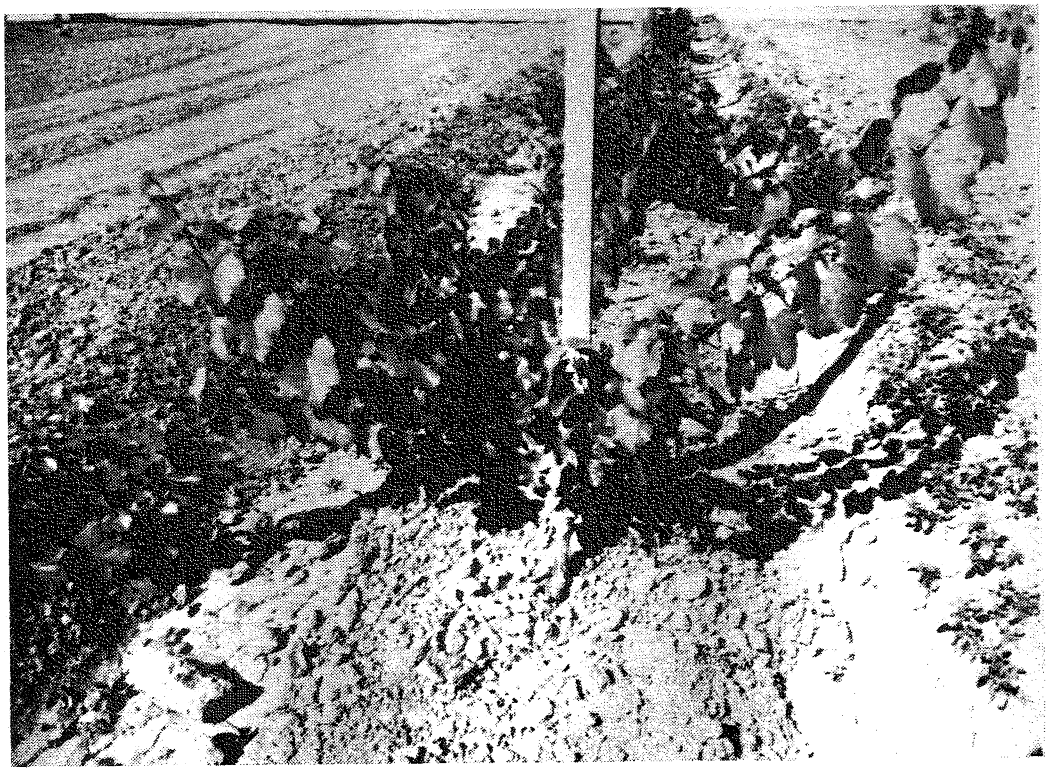


FIGURE 1-4. A three-year-old vine trained onto a two wire horizontal trellis.

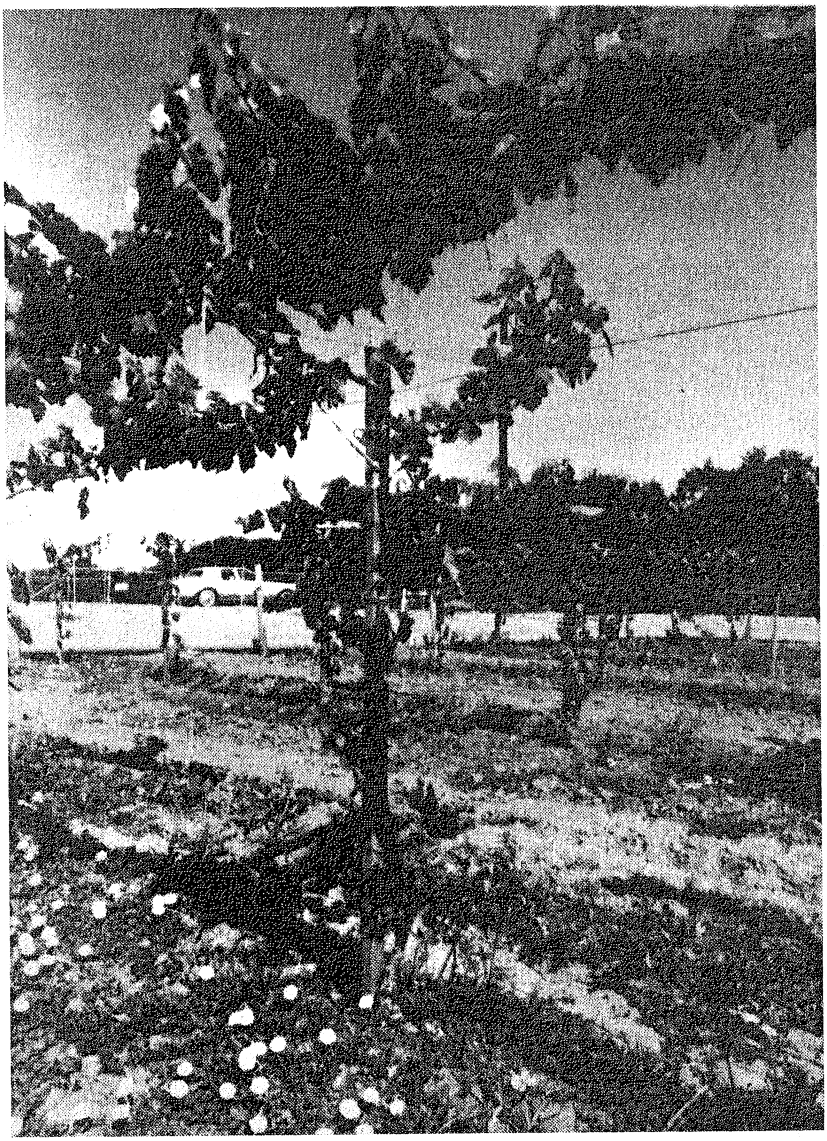
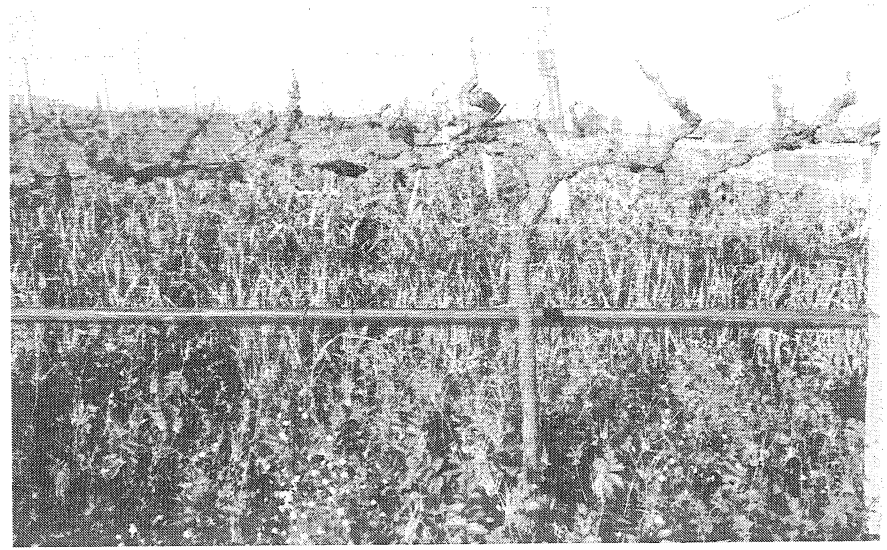


FIGURE 1-5. An example of cordon-spur pruned vines on a two-wire vertical trellis with drip irrigation.



of fruit served no purpose. Differences in vineyards, even adjacent ones, cause bigger quality differences in the wines. In the coastal areas with shallower soils, one can expect to get roughly about half to two-thirds the yield of the richer valley soils. Table 1-2 gives some general viticultural data gathered for a University of California Bulletin. Data are for conservative vineyard management to obtain optimum fruit quality in the coastal areas.

GRAPE MATURITY

Most people think of fruit maturity in terms of the sugar content of the grape. This is true in the warmer areas where grapes will accumulate as much as 26 grams of sugar per 100 ml of juice (°Brix value of 28°). Care is usually taken to pick the fruit for white table wine at 20.5°-22.5°Brix and the red table wine grapes at 21.5°-23.5°Brix. There is a very practical reason for this. If harvested in these ranges, the wine will have sufficient alcohol to give a sound wine which is balanced in taste and resistant to microbiological

Table 1-2. Yield Data for Some Common Wine Varieties Grown in Central Valley and Coastal Areas of California.

	Tons/acre			Tons/acre	
Cultivar	Central Valley	Coastal Area	Cultivar	Central Valley	Coastal Area
Barbera	8.2	4.3	Grenache	8.3	6.2
Cabernet Sauvignon	7.0	4.5	Pinot Noir	3.7	3.9
Carignane	9.0	-	Ruby Cabernet	7.9	5.1
Chardonnay	6.3	4.4	Sauvignon blanc	5.8	6.4
Chenin blanc	10.0	5.8	Semillon	6.4	3.9
French Colombard	7.1	5.9	White Riesling	4.9	4.3
Gewurztraminer	5.4	6.1	Zinfandel	-	4.1

Data from Amerine and Winkler (1963). Coastal area fruit was non-irrigated and on two-wire trellises. (If irrigated and larger trellises, increased crops would be expected.)

spoilage. Table 1-3 gives the approximate yields of ethanol that can be expected from white and red grapes picked at various °Brix values from cool and warm grape-growing areas.

Brix measurement, °Brix, can be measured with either a hydrometer or a refractometer. The refractometer is the most commonly used device for measuring sugar in grapes and the better models are temperature compensated. Less expensive models are not temperature compensated and the readings have to be corrected for temperatures different than those for which the refractometer is calibrated. The method for temperature corrections is given in Appendix III. Even with the temperature-corrected model, it is best to work as closely to the calibrated temperature as possible. You should also check your refractometer at the beginning of each season for accuracy.

Method for Checking Correctness of Refractometer

Weigh out 20 grams of sugar and dissolve in 80 grams of water. (If a gram scale is unavailable, measure out four ounces of sugar

Table 1-3. Effect of °Brix and climate on alcohol yield.

	Ethyl alcohol % v/v		
		Red grapes	
Brix	White Juice	Cool area	Warm area
18	10.0	9.7	9.0
19	10.7	10.3	9.6
20	11.3	10.8	10.2
21	12.0	11.4	10.8
22	12.6	12.0	11.2
23	13.2	12.7	11.9
24	13.9	13.3	12.4
25	14.5	13.8	13.0

and dissolve it in one pound of water.) This will give a 20°Brix solution. The refractometer should read 0° with plain water and 20°Brix with the sugar/water solution. If it does not give these readings, the instrument must be recalibrated. If the instructions do not give a method for calibration, return the refractometer to the factory for calibration.

Proper Care of Refractometers

Care should be taken to avoid scratching the prism (where the juice sample is applied). Never use a glass rod or other hard applicator. Use a soft applicator such as a rubber-tipped plastic rod. The prism should be dry when the sample is applied. Errors occur in refractometer readings when moisture is left on the prism, diluting the sample. If a previous sample is left to completely or partially evaporate, the residual sugar can cause a new sample to give a falsely high reading. The prism should be rinsed thoroughly and only lens tissue used to dry it.

Vineyard Sampling

Vineyard sampling should be done carefully and correctly. The following method is used by professional viticulturists. It is a scientific method and is simple to follow. Home winemakers and/or grape growers can easily make this evaluation if they are willing to spend the necessary time. For long-range planning, a record could be kept of these readings. Mark those vines chosen for sampling so that a new vine selection each time is unnecessary.

1. Select portions of the vineyard that will represent the entire vineyard. Variables such as soil depth (deep or shallow), vine age (young or old), etc., should be considered.
2. Choose percentages of vines from each which represents each group fairly.
3. Sample the designated or random vines by selecting 10 to 20 clusters or enough to have a representative selection from the vineyard. The clusters should include some near the trunk, middle and outer portions of the vines as well as the shaded and sunny areas.

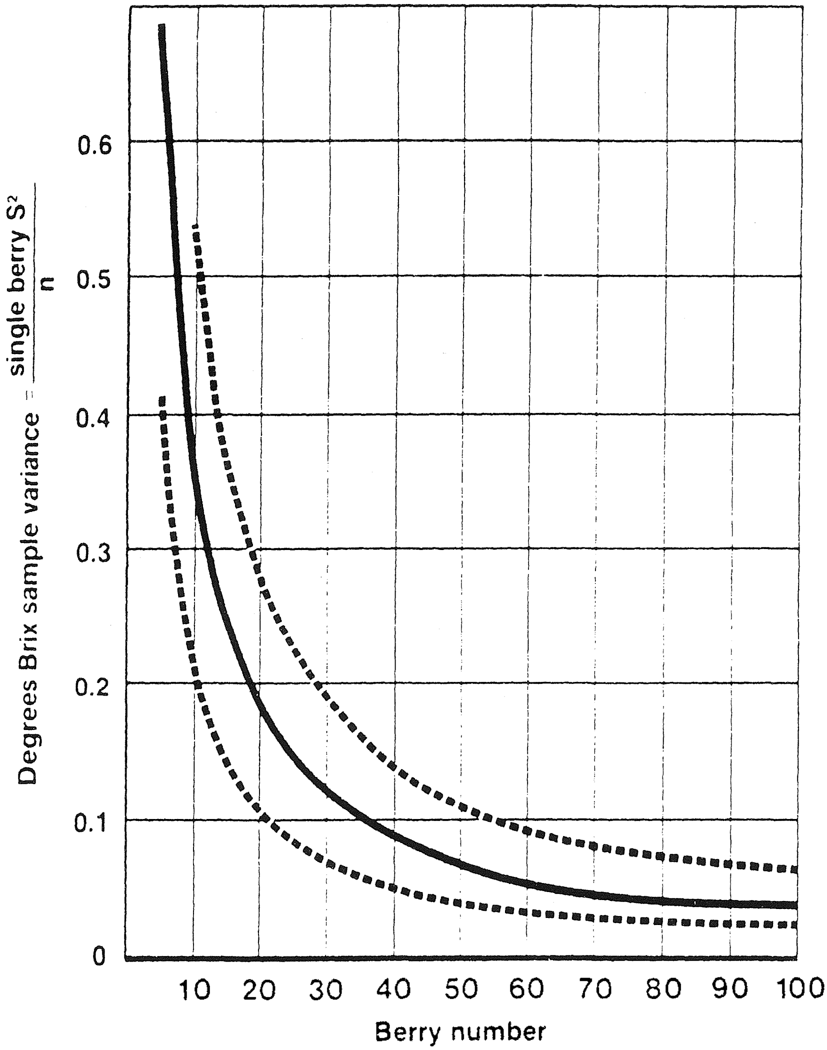
4. Pool the cluster samples. Crush and press them in a manner similar in severity of pressing to the method or processing that will occur when they are harvested. Be sure the resulting juice is well mixed.
5. Determine the °Brix. This is based on the recommendations of Kasimatis and Vilas (1985). Previous recommendations suggested use of berry sampling and other modifications which took extra time and gave little or no more accuracy. Figures 1-6 and 1-7 show the type of error to result from rational sampling. Sampling should begin at 16°Brix and weekly samples taken. It is worthwhile to plot the changes in °Brix against the intervals in time between samplings. A typical plot of these changes is given in Figure 1-8. This will allow one to predict the date of harvest several weeks in advance if data from previous years are available. It is also valuable to plot the total acidity and pH during the maturation period as shown. After a few years of data collection, the optimum harvest conditions can be determined. This is not absolutely necessary, but if the winemaker can make the latter two determinations, it will allow him/her the options of adjusting the acidity or pH.

A method which has been reported (Cooke and Berg, 1983) as a more popular method than the °Brix/acid ratio and the suggested replacement method of assessing the proper harvest time, is the °Brix $\times$ $(pH)^2$. This more properly relates to the true physiological maturity of the fruit. Whatever the criteria, the fruit for table wine should be harvested in a practical °Brix range. White table wine grapes are ready to harvest around 22°Brix and red table wine grapes about 23°Brix with pH values of 3.2-3.4 and 3.3-3.5, respectively. Alterations of the total acidity and pH can be adjusted by acid additions. In some states or countries, the °Brix can be altered by sugar additions but not in California.

Analysis

In this book, we give only the necessary simple analytical procedures. These can be done with a minimum knowledge of chemistry and require minimum equipment. These procedures are either given in Chapter 9 or in appropriate places throughout the text.

FIGURE 1-6. °Brix variances calculated for a range of berry sample sizes. Dotted lines indicate variance spread from the mean (Kasimatis and Vilas, 1985).



Degrees Brix variances calculated for a range of berry sample sizes. The solid line is the mean and the space between the broken lines is the expected variance spread.